# WATERTOWN ARSENAL LABORATORY

## MEMORANDUM REPORT

NO. WAL 710/617

**Resistance of a Light Gauge Mn-Mo Type Steel to Perforation by Standard Cal. .45 Ball Ammunition and by Fragment-Simulating Cal. .22 Projectile, G-2**



BY

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DATE 24 April 1944.

WATERTOWN ARSENAL
WATERTOWN, MASS.

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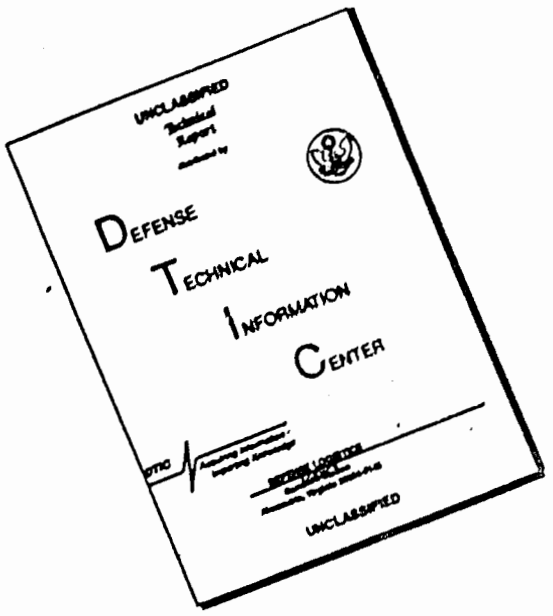


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Third Partial Report on Problem B-8.2

24 April 1944

# Resistance of a Light Gauge Mn-Mo Type Steel to Perforation by Standard Cal. .45 Ball Ammunition and by Fragment-Simulating Cal. .22 Projectile, G-2

1. In accordance with a request from the Office, Chief of Ordnance[1], a program of development of improved body armor components is in progress at this arsenal. In conjunction with this program tests have recently been conducted on samples of a Mn-Mo type steel manufactured by Jones and Laughlin Steel Corporation and heat treated by Breeze Corporations, Inc.

2. These samples of manganese-molybdenum type steel showed greater resistance to both types of projectiles in the ("as-quenched") condition than as tempered at 600°F., 700°F. or 800°F. In comparison with Hadfield manganese steel of the quality currently procurable under Specification AXS-1170, the ballistic limit of the best samples of this steel (as-quenched) is about equivalent under impact of standard cal. .45 ball ammunition, only in the .050" gauge, but is appreciably inferior under impact of the more significant cal. .22 fragment-simulating projectile G-2 in all gauges.

3. Samples of this steel, as quenched, and as tempered for 1 hour at 600°F., at 700°F. and at 800°F were received in nominal gauges .030", .040" and .050". From the 24" x 36" samples received, sections 12" x 12" were cut and tested, clamped rigidly to a wooden ballistic frame, with standard cal. .45 ball ammunition and with projectile G-2 (cal. .22, 17 grains) developed at this arsenal.[2] The results of these tests appear in Table I.

4. The ballistic limits of the .030" samples under impact of standard cal. .45 ball ammunition were so low that complete tests were not run, since resultant velocities cannot be well controlled in this range. Under impact of projectile G-2, the "as quenched" specimen had an appreciably higher ballistic limit (830 feet-per-second) than any of the other three specimens (775, 785 and 750 feet-per-second).

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1. O.O. 422.3/71(c) - Wtn 470.5/7443(c) dated 28 September 1943.

2. WAL Memorandum Report No. 762/253(c).

5. The ballistic limit of the .040" "as quenched" sample under impact of the cal. .45 projectile (699 feet-per-second) was considerably greater than those of the other specimens (494, less-than-409 and 459 feet-per-second) but is much inferior to that of Hadfield manganese steel currently procurable under Specification AXS-1170 (900 feet-per-second). Under impact of the fragment-simulating cal. .22 projectile G-2, however, although the ballistic limit of the "as quenched" specimen (1375 feet-per-second) is still much higher than that of the other specimens (1105, 1050 and 1055 feet-per-second), it is considerably inferior to that of average quality Hadfield manganese steel (1600 feet-per-second).

6. In the .050" gauge range, sample GT-3, tempered for 1 hour at 700°F., exhibited resistance characteristics equivalent to the "as quenched" samples under both types of projectile impact. The resistance of both samples to perforation by standard cal. .45 ball ammunition compared very favorably with average Hadfield manganese steel. Under impact of projectile G-2, all four samples had ballistic limits in excess of that of average Hadfield manganese steel. In the interests of accurate interpretation of these results, however, it should be pointed out that the considered limits of the Hadfield type steel are averages of run-of-the-mill stock and that higher limits have been attained in development tests conducted here.

7. The tendency for the ballistic performance of the heavier-gauge (.050") Mn-Mo type steel to approach and surpass that of the Hadfield type is consistent with the viewpoint that as the gauge increases (and the limit velocity likewise increases) the absolute deformability, prior to failure, of the Hadfield steel, from which much of its superiority to other steels emanates, will decrease, and simultaneously, the ballistic advantage attendant deformability will decrease (because of the shorter time consumed in perforation). Thus, the influence of tensile strength may be expected to become more important and that of ductility to become less important as the gauge increases.

8. The marked superiority of the "as quenched" samples in the lighter gauges seems hardly attributable entirely to the mere difference in hardness of the samples. It is suspected that the other samples have suffered an embrittlement somehow attributable to the tempering operation.

9. On the basis of these tests, development of this Mn-Mo type steel in the .050" gauge range is to be encouraged and further experimentation toward tempering this steel without embrittling it is indicated.

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TABLE I

Summary of Ballistic Tests Conducted at Watertown Arsenal on Samples of a Mn-Mo Type Steel Submitted by Jones and Laughlin Steel Corporation and Breeze Corporations

| Sample | Gauge | Chemical Composition C | Mn | Si | S | P | Mo | Tempering Temp. (°F.) 1 hr. | Hardness Rockwell "C" | Ballistic Limits G-21 | .45[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GU-1 | .028" | .23 | 1.19 | .19 | .020 | .017 | .33 | As quenched | 35 | 880 | - |
| GU-2 | .031" | .23 | 1.19 | .19 | .020 | .017 | .33 | 600° | 29 | 775 | - |
| GU-3 | .030" | .23 | 1.19 | .19 | .020 | .017 | .33 | 700° | 26 | 785 | - |
| GU-4 | .030" | .23 | 1.19 | .19 | .020 | .017 | .33 | 800° | 18 | 750 | 333 |
| GT-9 | .039" | .24 | 1.50 | .20 | .016 | .018 | .31 | As quenched | 41 | 1375 | 699 |
| GT-10 | .040" | .24 | 1.50 | .20 | .016 | .018 | .31 | 600° | 35 | 1105 | 494 |
| GT-11 | .038" | .24 | 1.50 | .20 | .016 | .018 | .31 | 700° | 34 | 1050 | less than 409 |
| GT-12 | .038" | .24 | 1.50 | .20 | .016 | .018 | .31 | 800° | 33 | 1055 | 459 |
| GT-1 | .049" | .24 | 1.50 | .20 | .016 | .018 | .31 | As quenched | 35 | 1913 | 1027 |
| GT-2 | .048" | .24 | 1.50 | .20 | .016 | .018 | .31 | 600°(?) | 29 | 1775 | 874 |
| GT-3 | .050" | .24 | 1.50 | .20 | .016 | .018 | .31 | 700°(?) | 37 | 1920 | 1042 |
| GT-4 | .054" | .24 | 1.50 | .20 | .016 | .018 | .31 | 800°(?) | 31 | 1883 | 817 |
| All plates above were quenched in oil at 125°F. from twenty minute re-heat at 1600°F. | | | | | | | | | | | |
| Hadfield manganese steel (average) | .040" | - | - | - | - | - | - | - | - | 1600 | 900 |
| Hadfield manganese steel (average) | .050" | - | - | - | - | - | - | - | - | 1750 | 1000 |

1. Cal. .22 (17 grains)

2. Standard cal. .45 ball ammunition (steel jacketed) 230 grains